ON THE PULSE MEASUREMENTS OF THE SEMI-CONDUCTOR RECTIFIERS

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1. Introduction

It is well known that we cannot get reproducible properties of the semi-conductor rectifiers because of creep or aging of the rectifiers. One method to get reproducible results is instantaneous measurement. For the present measurement, single pulse of rectangular wave form is used, although repeated pulsatory wave are usually used. The width of a pulse is varied from 0.2 micro-seconds to a few seconds.

2. Methods of Measurement

The rectifier is put in series with a standard resistance, and is connected with the pulse wave generator. Two peak-voltmeters of just the same construction are used, the one is put through the standard resistance and the other through the pulse generator, as shown in Fig. 1.

The voltage applied to the rectifier is read as the difference between the readings of two peak-voltmeters, and the current is get as the ratio of the values of the voltmeter and of the standard resistance. Each voltmeter endures maesuring up to about 400 volts.

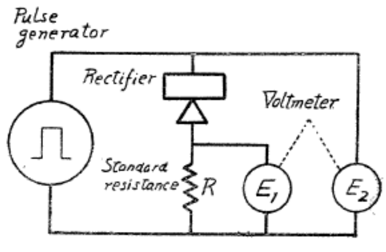

FIG. 1

The pulse generator is shown in Fig. 2. Operating the switch (S), the first tyratron tube TX-920 (V_1) starts, and the current flows into each resistance R_1 (about 200 ohms) and R_2 (about 400 ohms) from the battery (B) of about 600 volts. There generates a voltage drop of about 400 volts through the R_2. After a time of about CR seconds, where C and R are the capacity and resistance as shown in Fig. 2, the second tyratron tube TX-920 (V_2) starts, and abates the voltage through R_2 from about 400 volts to the arc voltage of the tyratron tube. We can thus get a pulse wave of rectangular form as shown in Fig. 2. With the suitable choice from the values of C and R, the wave width can be varied from 0.2 micro-seconds to a few seconds.

The whole circuit of the peak-voltmeter is shown in Fig. 4. Fig. 3 demonstrates the principles of the voltmeter.

The pulse voltage are imposed on the grid of the valve V_1, whose cathode are earthed through the auto-bias resistance R_1. The cathode-follower connections

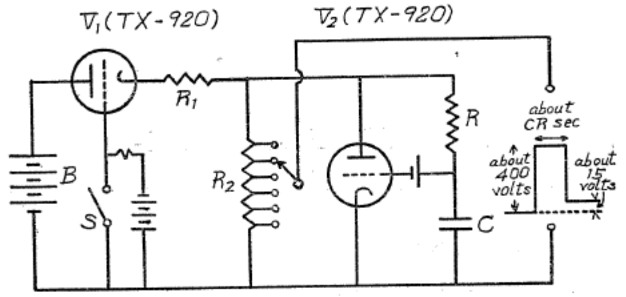

FIG. 2

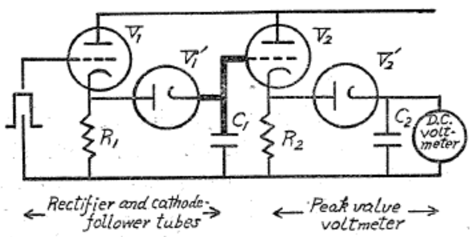

FIG. 3

are used in all parts of the circuits. The peak cathode voltage following the peak pulse grid voltage charges the condensor C_1 through the rectifying valve. After the peak voltage lapsed, the voltage of the condensor does not drop because rectifying valve does not admit any reverse current.

The time necessary for charging the condensor C_1 is about $(R_{V_1}+R_{V_1'})C_1$ where R_{V_1} and $R_{V_1'}$ are respectively the internal resistance of the valves V_1 and V_1'. To measure the peak pulse voltage in short duration, it is necessary to use a low impedance tube for V_1 and V_1' and a low capacity condensor for C_1 (for example less than 1000 micro-micro Farads), and parallel connection of valves is used both for V_1 and V_1'.

The voltage of the C_1 leaks because of (1) the automatic leakage of the C_1 (2) the leakage through the valve V_1' (3) the leakage from all parts of the leads shown in broad line in Fig. 3 (including the leakage through cathode to heater of the valve V_1' and through the heater transformer) and (4) the leakage by the grid current of the valve V_2.

All the leakages except (4) are positive and they might be chosen as small

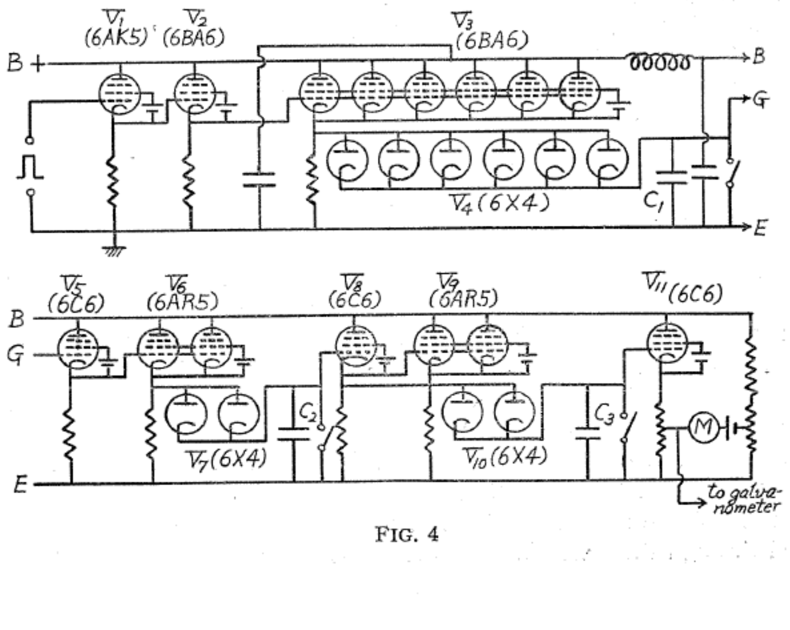

FIG. 4

as possible. The leakage current of (4) can be made negative if we take a large value for R_2 (about 100 to 1000 kilo-ohms) and with the suitable choice for the suppressor grid voltage. Ordinally battery of about 45 volts are adequate for this purpose. With the suitable choice of the valve V_2 above (6C6 are preferable) the negative leakage of (4) can just reduce the total leakage current from (1) to (3).

However precautions are taken against these leakages, it is not sufficient to maintain the voltage of the capacity C_1 constant for a sufficiently long time, while we are requested to observe the voltage of C_1 constant for the standing indication of a valve voltmeter. The whole circuit in Fig. 3 serves as an amplifier of wave width. Just as we cannot get high gain ampification by a single valve, so we need many cascade time amplifying apparatus of circuits as shown in Fig. 3 to amplify the wave width to the desired values. Three stages of cascade connections are used for each voltmeter, using the condensors whose successive capacity are about 0.0005, 0.01 and 0.5 micro-farad. The whole circuit of one of the voltmeters is shown in Fig. 4.

These two voltmeters E_1 and E_2 are of just the same construction and can measure the voltage covering the range from 50 to 400 volts with accuracy of about 0.1 volt. The difference of the values of E_1 and E_2 can be read more precisely with the accuracy of about 0.01 volt and they are used to measure the voltage across the rectifiers. They are measured with the galvanometer connected between the cathods of last valves of E_1 and E_2 as shown in Fig. 5.

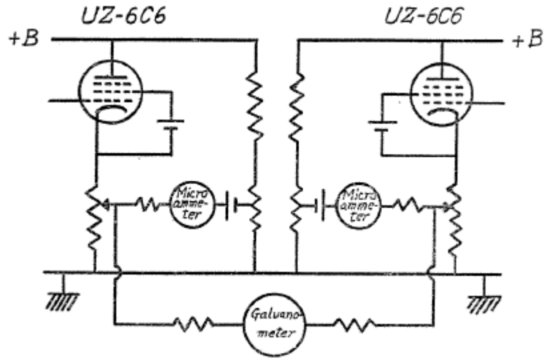

FIG. 5

Two voltmeters, E_1 and E_2 can be exchanged, and double weighed mean values are used for each value of voltage and their differences. The voltmeters are calibrated with the d.c. voltmeters in the range of long time pulses. The slighter reduces the indication of voltmeter, the narrower is the width, and this effect is preliminary measured.

3. Results of Measurement

The current-voltage characteristics of both plate and cats-whisker type rectifiers are measured at several readings of temperature and at various width of wave. The former has a large self-capacitance ordinally, and the measurement is of no significance for the pulse wave of less than about 10^{-5} second, whereas the latter can be measured with short pulses up to 0.2 micro-seconds.

When the rectifiers have self-capacitances, the charging currents are added to the ordinary currents after the onset of the pulses, and discharge current flows after the outset of the pulses. The conductance increases when measured with short pulses in the plate rectifiers, and this effect can well be understood by the parallel circuit of C and R, each of which we can get by the impedance measurements.

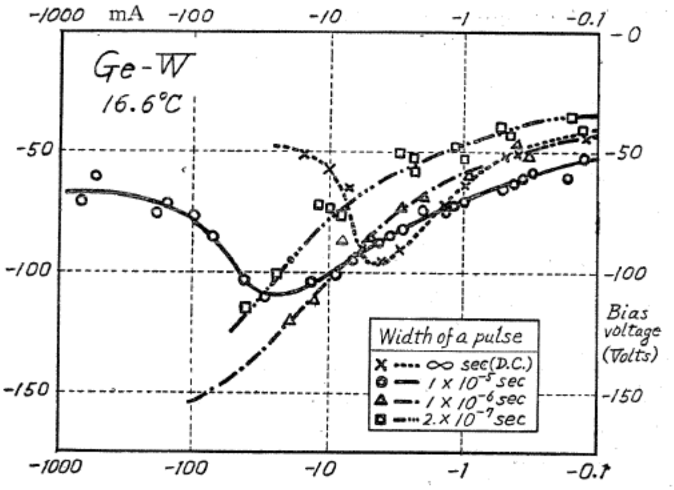

FIG. 6

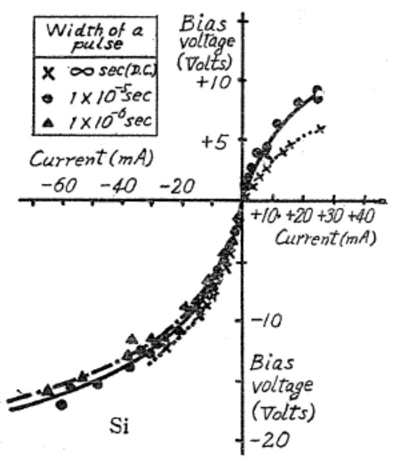

FIG. 7

Tungsten wires are used as whiskers for germanium and silicon rectifiers. Germanium is English made, and silicon was kindly supplied me by the Tokyo Shibaura Electric Co. and the Research Laboratory of Electric Communication.

Fig. 6 shows the current-voltage characteristics of germanium for the pulse width of 1×10^{-5}, 1×10^{-6} and 2×10^{-7} second. The d.c. characteristic shows a negative resistance as is well known. For long pulse width of 1×10^{-5} sec., its characteristic resembles that of d.c., and shows clearly negative resistance at large interval of current than that of d.c. Negative resistances will also exist for pulse widths of 1×10^{-6} or 2×10^{-7} sec., because there is a tendency that as the wave width

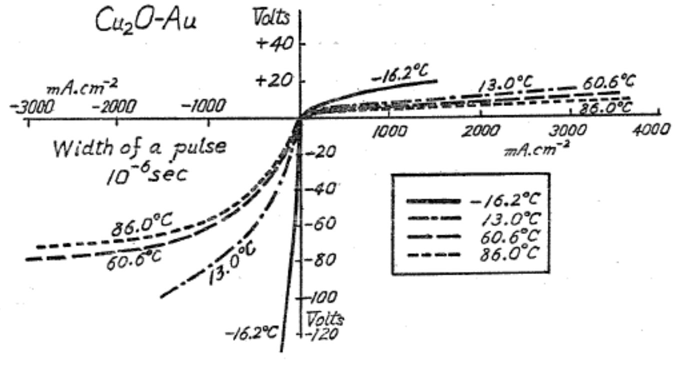

FIG. 8

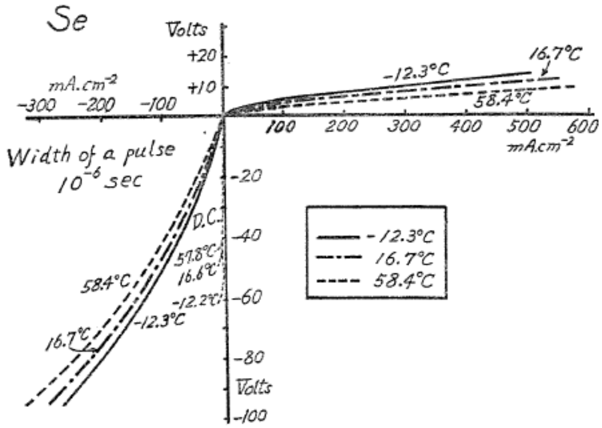

FIG. 9

are made short, the intervals of negative resistances shift to high current, so we may expect them at high intervals of current, which we could not be realized by the present experiment.[1] All these facts can be explained by the thermal effect.

Figs from 7 to 9 show the results got from silicon, cuprous oxide and selenium rectifiers respectively.

4. Conclusions

By the single pulse method for measuring, the semi-conductor rectifiers of germanium, silicon, cuprous oxide and selenium are measured with the pulse widths in the order of micro-seconds. Some of them are measured in strong fields or currents which have never been measured. The negative resistance of germanium is observed with the pulse wave broader than about 10^{-5} sec.

The author thanks Mr. T. Nakayama for helping him with experiment.

Reference

1) Cf. Bennett A. I. and Hunter L. P. **1951** Phys. Rev., 81, 152.